RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #14

Version 0.2 of the Draft for Proposed DO-260A Appendix O: Accommodation of Trajectory Change Reporting

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SUMMARY
The DO-242A includes preliminary requirements for Trajectory Change Reports. Although SC-186 has directed WG3 to not include the explicit support for TC Reports in DO-260A, WG3 has been requested to provide information on how TC Reports may be accommodated in a future update. This Working Paper is an update to 1090-WP-13-17.

References: 1. DO-242A, June 25, 2000
2. 1090-WP-13-17, August 20, 2002 (initial draft of Appendix O)

1. Introduction

The DO-242A includes preliminary requirements for Trajectory Change Reports. Although SC-186 has directed WG3 to not include the explicit provisions for TC Reports in DO-260A, WG3 has been requested to provide information on how TC Reports may be accommodated in a future update to the MOPS. This Working Paper proposes a new appendix to DO-260A that would provide preliminary information on how TC Reports, and the associated extended squitter messages, could be supported as well as an assessment of the expected performance.

TC Reports are an extension to the Trajectory Change Point reporting that was described in both DO-242 and DO-260. RTCA SC-186 in preparing DO-242A concluded that the previously defined TCP reporting provisions were not sufficient for the intended purpose. The preliminary requirements reflected in DO-242A for TC Reports are intended to accommodate a variety of different airborne capabilities in terms of onboard data sources for intent information. As a result there are several variations possible of the required contents for TC Report. However, for the purpose of the proposed MOPS Appendix this level of detail is not addressed.

2. Proposal

The working group is requested to review the proposed new appendix to DO-260A that describes how TC Reporting may be accommodated in future versions of these the 1090 MHz ADS-B MOPS. The new appendix cannot be completed until after additional modeling results are available providing and indication of the performance that could be achieved for differing trajectory change message transmission rates and under differing operational scenarios (i.e., low density, LA2020 and core Europe).

ATTACHMENT

-DRAFT Version 0.2 -

Appendix O

Accommodation of Trajectory Change Reporting

O.1. Introduction

The DO-242A includes preliminary requirements for Trajectory Change Reports. Due to the level of maturity of the TC Reporting requirements, it was decided that it would not be appropriate to include explicit support for TC Reports in these MOPS. However, provisions have been made within the 1090 MHz ADS-B message structures to facilitate the future addition of the information required to support TC Reporting. This appendix provides information on how TC Reports and the associated 1090 MHz ADS-B messages may be accommodated in a future update to these MOPS. This appendix also provides a preliminary assessment of the expected performance that would be associated with the reporting of trajectory change information.

TC Reports are an extension to the Trajectory Change Point (TCP) reporting that was described in both DO-242 and DO-260. During the update to the ADS-B MASPS to version DO-242A it was concluded that the previously defined TCP reporting provisions were not sufficient for the intended purpose. The preliminary requirements reflected in DO-242A for TC Reports are intended to accommodate a variety of airborne capabilities. Thus some aircraft may broadcast only a subset of the TC information allowed for by DO-242A in the TC report structure. Section 2.1.2.19.2 of DO-242A describes the operational requirements for TC reporting and section 3.4.8 of DO-242A provides the technical and performance requirements for TC reporting. DO-242A does not define the minimum set of TC related parameters that must be broadcast. DO-242A defines preliminary requirements for reporting of information related to a first through forth point at which the aircraft trajectory will change. The associated reports are designated as TC+0, TC+1, TC+2 and TC+3 reports. DO-242A suggests that additional TC reports may ultimately be defined. This appendix specifically addresses only the accommodation of TC+0 and TC+1 reports with an indication on the potential support for additional TC Reports.

O.2. Summary of Trajectory Change Reporting Requirements

DO-242A, Table 3-24 defines the content requirements for TC+0 and TC+n Reports. The broadcast of messages supporting TC+0 reports will be required for all Class A2 and Class A3 ADS-B equipped aircraft, as per DO-242A, Table 3-3(a). The broadcast of messages supporting TC+n reports would only be required of Class A3 ADS-B equipped aircraft, as per DO-242A, Table 3-3(a). Table O-1 below defining the requirements for TC Report content is a simplified version derived from the Table 3-24 of DO-242A.

Table O-1: Trajectory Change (TC) Report Definition

	TC Report Elem. #	Contents [Notes] [Resolution or # of Bits]	Needed Only For TC+0 Reports
ID	1	Participant Address [24 bits]	
	2	Address Qualifier [1 bit]	
TOA	3	Time of Applicability [1 s resolution]	
TC Report #	4	TC Report Sequence Number [2 bits]	
TC Report Version	5a	TC Report Cycle Number [2 bits]	
	5b	(Reserved for TC Management Indicator) [3 bit]	•
TTG	6	Time To Go [4 s resolution]	
Horizontal TC Report Information	7a	Horizontal Data Available and Horizontal TC Type [4 bits]	
	7b	TC Latitude [700 m or better]	
	7c	TC Longitude [700 m or better]	
	7d	Turn Radius [700 m or better]	
	7e	Track to TCP [1 degree]	
	7f	Track from TCP [1 degree]	
	7g	(Reserved for Horizontal Conformance) [1 bit]	•
	7h	Horizontal Command/Planned Flag [1 bit]	
Vertical TC Report Information	8a	Vertical Data Available and Vertical TC Type [4 bits]	
	8b	TC Altitude [100 ft resolution]	
	8c	TC Altitude Type [1bit]	
	8d	(Reserved for Altitude Constraint Type) [2 bits]	
	8e	(Res. for Able/Unable Altitude Constraint) [1 bit]	•
	8f	(Reserved For Vertical Conformance) [1 bit]	•
	8g	Vertical Command/Planned Flag [1 bit]	

O.3. 1090 MHz ADS-B Messages for Trajectory Change Information

The trajectory change information will be broadcast from the aircraft using a Trajectory Change (TC) Message. Message TYPE CODE 27) has been reserved for this purpose as indicated in Table 2-11 of this MOPS. For message TYPE CODE 27 a SUBTYPE subfield will be defined with as a minimum of 4 codes reserved for conveying the trajectory change information associated with TC+0 and TC+1 Reports (as required by DO-242A). Allowing for a 3-bit Subtype subfield, the TYPE CODE plus the SUBTYPE code would occupy the first 7 bits of the 56-bit ME field of the extended squitter. This results in the 49 remaining bits being available to convey the trajectory change information. With this limitation on the transmission frame size, the broadcast of trajectory change information will need to be segmented. Two messages will be required to convey the complete set of information defined for a complete TC+0 or a TC+n Report. The preliminary concept would be to define the 4 Message SUBTYPES as:

SUBTYPE=000	TC+0 Basic Information
SUBTYPE=001	TC+1 Basic Information
SUBTYPE=010	1st Supplemental TC Message
SUBTYPE=011	2nd Supplemental TC Message
SUBTYPES=100 through 111	reserved for TC+n Information

For Subtypes 000 and 001 there would be 49 bits available to convey the basic information needed for generation of TC+0 and TC+1 reports. Subtypes 010 and 011 would be used for messages that convey the additional information necessary to generate a TC+0 or a TC+1 reports

that is beyond the basic TC information being conveyed in the SUBTYPE=000 or 001 messages. The message format for conveying TC supplemental information will use the TC Report Sequence Number and the TC Report Cycle Number to allow the Supplemental TC information to be correctly associated the intended basic TC messages.

Table O-2 below shows how the information required for a TC+0 and TC+1 reports would be conveyed by the 1090 MHz ADS-B messages.

Table O-2: Trajectory Change Report Mapping to 1090 MHz ADS-B Messages

	TC Report Elem. #	Contents	How conveyed by 1090 MHz ADS-B Messages	Target State and Status Message SUBTYPE (ME Message bits required)		
				TC+0 Basic	TC+1 Basic	Supplemental TC
ID	1	Participant Address	Conveyed in Message Header	0 bits	0 bits	0 bits
	2	Address Qualifier	Conveyed in Aircraft ID and Type Message	N/A	N/A	N/A
TOA	3	Time of Applicability	Added by Receiver	N/A	N/A	N/A
TC Report #	4	TC Report Sequence Number	Target State and Status Message	3 bits (conveyed by Subtype Code)	3 bits (conveyed by Subtype Code	3 bits (conveyed by Subtype Code
TC Report Version	5a	TC Report Cycle Number	Target State and Status Message	2 bits	2 bits	2 bits
	5b	(Reserved for TC Management Indicator)	Target State and Status Message	N//A	N/A	[note 1]
TTG	6	Time To Go	Target State and Status Message	9 bits	9 bits	N/A
Horizontal TC Report Information	7a	Horizontal Data Available and Horizontal TC Type	Target State and Status Message	4 bits	4 bits	N/A
	7b	TC Latitude	Target State and Status Message	8 bits	8 bits	N/A
	7c	TC Longitude	Target State and Status Message	8 bits	8 bits	N/A
	7d	Turn Radius	Target State and Status Message	N/A	N/A	7 bits
	7e	Track to TCP	Target State and Status Message	N/A	N/A	9 bits
	7f	Track from TCP	Target State and Status Message	N/A	N/A	9 bits
	7g	(Reserved for Horizontal Conformance)	Target State and Status Message	N/A	N/A	[note 1]
	7h	Horizontal Command/Planned Flag	Target State and Status Message	1 bit	1 bit	N/A
Vertical TC Report Information	8a	Vertical Data Available and Vertical TC Type	Target State and Status Message	4 bits	4 bits]	N/A
	8b	TC Altitude	Target State and Status Message	10 bits	10 bits	N/A
	8c	TC Altitude Type	Target State and Status Message	1 bit	1 bit	N/A
	8d	(Reserved for Altitude Constraint Type)	Target State and Status Message	N/A	N/A	[note 1]
	8e	(Reserved for Able/Unable Altitude Constraint)	Target State and Status Message	N/A	N/A	[note 1]
	8f	(Reserved For Vertical Conformance)]	Target State and Status Message	N/A	N/A	*[note 1]
	8g	Vertical Command/Planned Flag	Target State and Status Message	1 bit	1 bit	N/A
Spare Bits				0	0	19
ME Bits for TYPE CODE				5	5	5
TOTAL ME Bits				56	56	56

* ***Notes:*** *1. Report elements indicated by DO-242A as reserved are not assigned bits. If required by a future MASPS revision, such report elements would be accommodated within a Supplemental TC message using the "spare" bits.*

O.4. Transmission Rate Requirements

DO-242A does not define the TC+0 or TC+1 report update rate requirements. However, Appendix N to that document provides an estimate for TC+0 reports where the air-to-air update rates are range dependent. DO-242A, Table N-8 defines a nominal update intervals at 95% probability for TC+0 reports as:

R < 20 NM --- Update Interval = 12 seconds (Class A2 and A3 systems)
R = 40 NM --- Update Interval = 18 seconds (Class A2 and A3 systems)
R = 90 NM --- Update Interval = 41 seconds (Class A3 systems)

DO-242A, Table N-8 also defines a 12 second update interval following a TC+0 state change at ranges to 40 NM.

No update rates are provided for air-to-ground delivery of TC information nor is the role of the ground ATM system adequately considered in the operational concept presented in of DO-242A, Appendix N.

The 1090 MHz ADS-B TC messages required to support conveying the complete information defined by DO-242A for a TC+0 Report includes both the TC+0 Basic and the 1st Supplemental TC messages. However, it may be possible to transmit the TC+0 Basic message at a higher rate than the TC Supplemental message since the TC+0 Basic message provides the most essential information and a small delay in receiving updates to the supplemental information may be acceptable. It is also probable that some or perhaps many Class A2 and A3 aircraft will not be equipped to provide other then the basic TC information, in which case the Supplemental TC message would not be required. It is not possible at this time to establish the specific update rate requirements for the individual data elements defined by DO-242A for the TC+0 reports. As the concepts and applications that use TC reports mature this may become possible. The other 1090 MHz ADS-B messages and their associated nominal broadcast rates that will routinely be broadcast for an airborne Class A2 or A3 system are:

Position:	2.0 per second
Velocity:	2.0 per second
A/C ID & Type:	0.2 per second
Operational Status:	0.4 per second
Target State:	0.8 per second
Total	5.4 per second

These MOPS, as well as the Mode S Transponder MOPS (DO-181c) limit the total transmission rate of all extended squitters to 6.2 per second. This means that if implemented under the current overall rate limit of 6.2 squitters per second, the broadcast of Trajectory Change information would need to be limited to not more than 0.8 messages per second. Given this current overall limit of 6.2 squitters per second only TC+0 can bed considered and supported. Support for TC+1 messages will require an increase in the overall rate limit. Since the complete set of TC information requires both a TC+0 Basic plus a TC Supplemental message there are two alternatives.

1. Broadcast each the TC+0 Basic and the associated Supplemental TC messages at a rate of 0.4 (i.e., at 2.5 second intervals).

2. If it is deemed appropriate to update the data elements contained in the Supplemental TC message at a lower than the information included in the TC+0 Basic message then it may be appropriate to broadcast the TC+0 Basic message at perhaps 0.5 messages per second and the TC+0 Supplemental message at perhaps of 0.3 messages per second.

Even support for TC+0 could be enhanced by allowing for a total extended squitter broadcast rate above the current limit of 6.2 squitters per second. Ideally the TC+0 related messages, or at least the TC+0 Basic message would be broadcast at the same rate as that used for the Target State messages (0.8 per second). If both the TC+0 Basic and TC+0 Supplemental messages were each to be broadcast at 0.8 per second then the maximum extended squitter broadcast rate would need to be raised to 7 per second.

Accommodating both TC+0 and TC+1 related messages will require the maximum allowed extended squitter rate to be increased to at least 7 squitters per second and more realistically to perhaps on the order of 8 squitters per second.

These above suggested maximum rates are considered appropriate to satisfy the DO-242A preliminary requirements and estimates for aircraft-to-aircraft reporting of Trajectory Change information in moderate to perhaps high density airspace. In low density airspace the reception probabilities increase due to lower 1090 MHz fruit rates and as a result, more modest transmission rates would suffice to support the required reception ranges and TC report update rates. Also, the operational use of intent information for the air-to-air case may be operationally limited in high density airspace. This could be the situation where the use of intent information in support of separation assurance and de-confliction are ground based applications and the performance requirements associated with the delivery of TC messages are limited to the air-to-ground case. In the case of air-to-ground delivery of TC messages on the 1090 MHz link, substantially higher probabilities of message reception apply as compared to the air-to-air case and the required update rates can be achieved at substantially lower transmission rates than would be required for an air-to-air service. However, there is still uncertainty as to the role for air-to-air versus to air-to-ground delivery of Trajectory Change information. At this point, DO-242A provides no validated operational concept for the use of TC information. It will not be possible to define an optimized set of TC related technical provisions for a future version of these MOPS until the operational concepts requiring TC information in the air and on the ground have been developed, validated and accepted for operational use. Also, once such operational requirements are established, it would need to be investigated whether the air-to-ground delivery of TC information could better served via an addressed data link rather than via ADS-B.

O.5. Estimated Performance

TBD

O.6. Other Factors and Issues

TBD